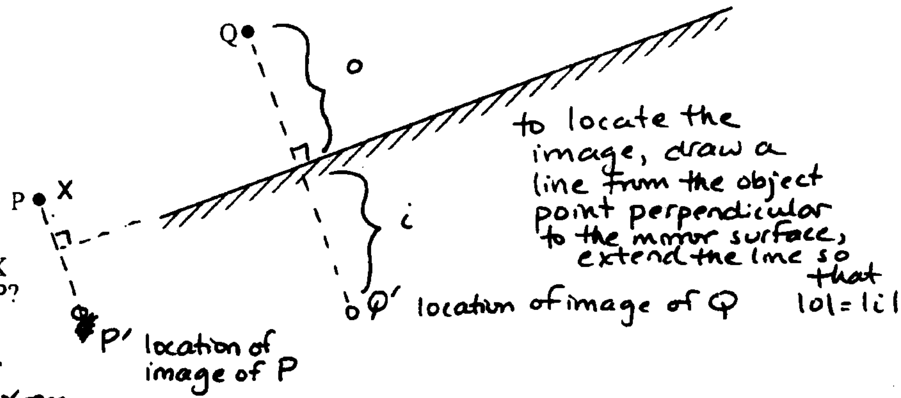
Name (please print): *SOLUTION* (last) (first) Total Points:_____

1. [25 pts] Parts A, B, and C are independent.

A. [~~10~~ pts] 8 pts Two point objects, P and Q, are near a plane mirror, as shown at right.

i. On the diagram, sketch and clearly label the location of the image of each object.



ii. Is an observer located at point X able to see the image of object P? Explain.

No. No rays originating at P can be reflected from the mirror and pass through point X. (Angle of incidence = angle of reflection.)

B. [~~15~~ pts] 12 pts A converging lens of focal length $f = 20$ cm produces a real image that is focused on a screen. The image is 40% the size of the object. The object is a light in the shape of an upright arrow.

i. How far from the lens is the object? *The image is real*

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f} \quad (1) \qquad \left|\frac{i}{o}\right| = .4 \quad (2)$$

Equation (1) & (2) ⇒ $o = 70$ cm

ii. Explain how, if at all, what you see on the screen would change if the top half of the lens were covered.

The image would be dimmer as fewer rays from the object are focused on the screen.

iii. Explain how, if at all, what you see on the screen would change if the lens were removed.

There would be no image without a lens. Therefore the screen would be (almost) uniformly bright (or dim).

C. [5 pts] A person has a *near point* of 280 cm. Corrective lenses are prescribed to enable the person to see clearly a computer monitor at 30 cm. What is the optical power of the lenses? (Ignore the distance between the eye and the lenses.)

A converging lens can be used to create an image at 280 cm from the eye. The image will be on the same side of the lens as the object and will be VIRTUAL.

$o = 30$ cm

$i = -280$ cm

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f} \Rightarrow f = .34\text{ m}$$

$$P = 1/f = 2.9\text{ D}$$

Name (please print): SOLUTION 123 C total points:______

(last) (first)

[25 points]

2. A plane wave of monochromatic green light (λ = 500 nm) is incident normally upon two identical narrow slits (the widths of the individual slits are much less than λ). The slits are separated by a distance d = 30 μm. An interference pattern is observed on a screen located a distance L away from the slits ($L \gg d$). The first dark fringe is located at point P, 1.5 cm from the center of the pattern.

[7 points] Consider the following student statements.
"If we double the wavelength of the incident light, point P becomes a location of maximum constructive interference. We originally had $\Delta D = \frac{1}{2}(\lambda)$ so if the wavelength is doubled we now have $\Delta D = \frac{1}{2}(2\lambda) = \lambda$ and this is the condition for maximum constructive interference."

Do you agree or disagree with this student? Explain your reasoning.

Disagree. If the λ gets larger the ΔD to the 1st min must get larger since ΔD is $\lambda/2$ for the first min and now the λ is larger. In order to have ΔD get larger the angle θ from the normal to the 1st min must increase therefore the 1st min will move away from the central bright fringe indicating that point P is between max constructive interference and a min.

In each part below, one change is made to the original situation (i.e., in each case, all parameters not explicitly mentioned remain as described above). For each case, state whether or not the light intensity at point P would remain zero. If not, will P become the location of a maximum constructive interference (bright) fringe? If point P is located between a bright and dark fringe state that explicitly. Explain your reasoning for each case.

i. [6 points] One of the two slits is made slightly narrower, so that the amount of light passing through it is less than that through the other.
If one slit is made narrower less light will go through that slit which means the amplitude of one of the waves would be less than the other. This is similar to what we observed with water in tutorial. This means point P will no longer be completely dark since a crest and a trough no longer completely cancel. P will not become a maximum because the waves will still be 180° out of phase.

ii. [6 points] The two slits are replaced by a single slit whose width is exactly 60 μm.
The first min for a single slit occurs when the light coming from the edge of the slit has a path difference of $\lambda/2$ with the light coming from the middle of the slit. This means that the light coming from the edge would have to cancel with the light coming from 30 μm away. This is the same as the initial situation so the 1st min would still be in the same place.

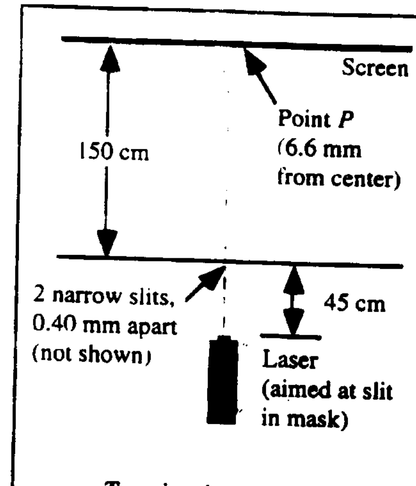
iii. [6 points] The region between the slits and the screen is filled with a material with an index of refraction n = 2.0.
If we replace the air with a material with an index of refraction of n = 2.0 this means the light will travel half as fast and since the frequency remains the same the wavelength must decrease by 1/2 so our new λ is 250 mm. If the wavelength decreases we would need less of an angle for a path difference of $\lambda/2$ so the angle from the normal to the position of the first min would decrease. We know from the first part that $\Delta D = \lambda/2$ = 250 nm to point P. But this path difference now corresponds to λ_{new} which means that this is constructive interference.

Name (please print) SOLUTION
last first

Total ________

3. [25 pts] Parts A and B are independent.

A. [12 pts] Laser light ($\lambda = 640$ nm) is incident on a mask containing two very narrow slits that are 0.40 mm apart. The laser is 45 cm from the mask, and the mask is 150 cm from the screen.



Top view (not to scale)

i. Point P is 6.6 mm to the right of the center of the pattern. Is point P *a maximum, a minimum,* or *neither?* Explain your reasoning.

$\sin\theta \approx \frac{y}{D} = \frac{6.6 \text{ mm}}{150 \text{ cm}}$

$d\sin\theta = m\lambda \Rightarrow m = \frac{dy}{\lambda D} = 2.75$ NOT an integer so neither a max (nor a min)

ii. If the distance between the mask and the screen were doubled, would the distance between the center of the pattern and the first minimum be *doubled, more than doubled, less than doubled,* or unchanged? ~~Explain.~~

$\sin\theta = \frac{y}{D}$ $y = D\sin\theta$

$\sin\theta$ remains the same, so if D is doubled, y is also doubled

B. [13 pts] The photograph at right shows the pattern that appears on a screen in a *different* double slit experiment.


Pattern on screen (part B)

m = 0 ↑ 0 1

i. Could the distance between the slits be 3.5λ? Explain how you can tell from the photograph. NO.

There are at least 5 minima to either side of the central bright fringe, corresponding to $\Delta D = \lambda/2, 3\lambda/2, 5\lambda/2, 7\lambda/2, 9\lambda/2$

If the separation of the slits were 3.5λ the MAXIMUM possible ΔD would 3.5λ or $7\lambda/2$. (Therefore $d \geq 4.5\lambda$ here.)

ii. If the distance between the slits were decreased, would the location of the second maximum to the right of the center of the screen (labeled "x" in the photograph) change? If so, would it move *farther from* or *closer to* the center of the screen? Explain your reasoning.

If the distance between the slits were decreased, the minima would be farther apart (and so would the maxima).

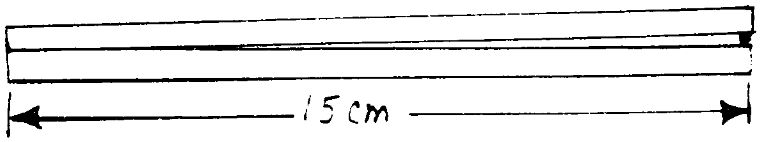
maxima occur where $d\sin\theta = m\lambda$ and $\sin\theta = \frac{y}{D}$

$\Rightarrow \frac{dy}{D} = m\lambda$

$y = \frac{m\lambda D}{d}$ $\Rightarrow$ if d gets smaller, y gets bigger

Name: SOLUTION (last) (first) Total points: ______

Prob. 4) Two flat rectangular glass plates (index of refraction n=1.52) are separated at one edge by a 10 μm diameter wire as shown below. The plates are illuminated from above by a sodium lamp (λ =589 nm). You study the light reflected from the film.



a. (4 pts.) Will there be a dark fringe or a bright fringe at the edge where the plates touch? Explain. DARK FRINGE

reflected wave from bottom of upper plate ($n=1.52 \to n=1$) is out of phase with the reflected wave from top of lower plate ($n=1 \to n=1.52$). These 2 waves cancel

b. (8 pts.) What is the total number of bright fringes you will observe?

get a bright fringe every time the path length up & down between the plates increases by λ

$$\therefore N = \frac{2(10\,\mu m)}{\lambda} = \frac{20\,000\,nm}{589\,nm} = \boxed{34}$$

The wedge-shaped gap is now filled with soapy water (index n=1.33).

c. (4 pts.) Are the fringes brighter or fainter than before the water was in place? Explain.

FAINTER The reflection coefficient is related to the change in n.
For air/glass $\Delta n = 0.52$, for water/glass $\Delta n = 1.52 - 1.33 = 0.19$

d. (4 pts.) Are the fringes closer together or farther apart than before the water was in place? Explain. CLOSER TOGETHER

Wavelength in water is shorter than in air $\left(\lambda' = \frac{589\,nm}{1.33}\right)$ so a shorter distance gives a phase of 2π.

e. (5 pts.) A thin soap film, illuminated by white light, is held vertically and you observe the light reflected from the film. After a minute, the top of the film appears dark. What color do you see just below the dark region? Explain.

VIOLET (OR BLUE) The 1st bright fringe below the dark spot occurs when the film thickness $d = \lambda/4n$. Since the film is thinnest at the top the first bright fringe will occur for the shortest visible wavelength.